



Blue Sky Foundation of North Carolina

Evaluation of Energy Efficiency and Moisture Retention in Manufactured Homes in Three North Carolina Counties

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Blue Sky Foundation of North Carolina Evaluation of Energy Efficiency and Moisture Retention in Manufactured Homes in Three North Carolina Counties

The Blue Sky Foundation of North Carolina Inc., in coordination with the Florida Solar Energy Center (FSEC), conducted an evaluation of energy efficiency and the build up of moisture in 16 North Carolina homes in the Summer of 2001. The Blue Sky Foundation proposed that the field evaluation of energy and moisture focus on the integrity of the building, duct systems and the moisture impact of un-vented space heaters. All of the homes were manufactured models located in three coastal North Carolina counties: Carteret, Dare, and New Hanover. FSEC trained the field crews and provided evaluation expertise on the data gathered for the final technical report. Blue Sky Foundation also contracted with Clemson University to provide field crews, and Charles Dugger of Blue Sky Foundation oversaw the field activities.

The Work Statement between FSEC, the Blue Sky Foundation and Clemson University was detailed as follows:

Task 1: The Blue Sky Foundation will research county records to locate homes and document their locations relative to hazards, soil type, energy company and on-site survey work.

Task 2: The Blue Sky Foundation will phone homeowners to determine hazard impacts of recent storms, qualify and secure rights to do on-site evaluations, and screen for moisture/energy problems and for un-vented heaters.

Task 3: The Blue Sky Foundation will develop an Access database to store data according to FSEC field protocol. See the Appendix for an example of the database form.

Task 4: Florida Solar Energy Center (FSEC) personnel will train Clemson crews to use equipment provided by FSEC for the on-site energy/moisture evaluation.

Task 5: The Clemson field crews will do a minimum of 15 field evaluations that will include moisture/energy tests (duct blaster, moisture and site surveys and picture documentation of duct integrity) according to FSEC protocol. The goal is to evaluate 20 homes.

The moisture survey will consist of visual inspection and an interview with the homeowner (no building shell penetrations will be part of this study).

Visual inspections of duct integrity and moisture in homes not included in the energy/moisture evaluation will be documented while the Blue Sky Foundation is studying other homes so they can be compared to the 15 homes involved in this proposed study.

Blue Sky Foundation staff and Clemson University field crews also evaluated the foundation and anchor structure of each of these 16 homes. Furthermore, each of the occupants filled out a survey asking for information about repairs they made to the

home and their level of satisfaction with the home. The results of these other data collections is reported in a separate document titled, "Evaluation of Anchor System Integrity and Occupant Satisfaction." A procedural manual detailing the steps involved in each evaluation is also available from the Blue Sky Foundation.

The following information was presented to the Blue Sky Foundation by FSEC. The report details the background related to FSEC's wider data collection effort to study energy and moisture problems in manufactured homes located in hot, humid climates. However, the Results section was prepared by the Blue Sky Foundation and only includes the 16 homes evaluated by the Blue Sky Foundation and Clemson University in coastal North Carolina

Manufactured Homes in Hot, Humid Climates

In 1999, the U.S. Department of Energy (DOE) competitively selected the Florida Solar Energy Center (FSEC) as the Building America Industrialized Housing Partnership (BAIHP) team leader. This group's primary function is to serve the manufactured housing industry by fostering technology-based innovations that will increase energy efficiency through a systems engineering of the whole house. The systems engineering approach considers the interaction between the building site, envelope, and mechanical systems, as well as other factors.

A significant number of manufactured houses in the Southeast are experiencing serious moisture problems (mushy drywall, sagging ceilings, extensive mold etc.). The problems are appearing in newly built homes constructed after the 1994 HUD code went into effect. The problems are related to leaky ducts, oversized air conditioning systems, owners desirous of a low set point temperature (around 70F), exhaust only ventilation systems, and presence of vinyl covered wallpaper resulting from the new HUD code. Requests to conduct diagnostic tests in moisture-related problem homes and recommend cost-effective solutions have been received from various HUD code manufacturers.

To satisfy this request, the following tasks were to be conducted by FSEC.

- Diagnostic tests on a number of problem homes experiencing moisture problems.
- Working with BAIHP partners to effect permanent change in designing and manufacturing air distribution and ventilation systems in manufactured homes
- Conducting a Building Science seminar for Manufactured Homes at FSEC
- Conducting training activities to educate state and third party inspection agencies for HUD code homes in the causes and solutions to problems
- Initiating detailed monitoring of two side by side homes to determine the effectiveness of recommended solutions in reducing moisture buildup in manufactured homes

In 2000, the BAIHP team was approached by the Manufactured Housing Research Alliance (MHRA) to work jointly on the moisture-related issues plaguing a number of HUD code homes built for the hot and humid climate of the Southeast.

Goal

This project will develop the tools, building methods and information needed to eliminate most of the underlying causes of moisture problems in manufactured homes sited in hot-humid climates. To accomplish this goal the effort will provide the following: (1) a characterization of the design, construction and operation factors contributing to moisture problems in manufactured homes in hot-humid climates; (2) demonstrate through field investigations, laboratory analysis and simulation, alternatives to current methods of construction that mitigate the chances of developing moisture problems; (3) develop cost-effective component designs and manufacturing methods that will significantly reduce the odds of future moisture problems; and (4) disseminate project results to industry and consumers.

Background

MHRA recently completed an effort that included documenting moisture problems in manufactured homes and suggesting steps that home manufacturers, installers and homeowners can take to avoid moisture related damage in new homes. The effort revealed a gap in our understanding of the factors that contribute to moisture problems in hot, humid climates, an area where there has been a recent upsurge in the number of moisture related problems reported. Further, anecdotal evidence suggests that some building practices encouraged by the HUD standards, may be exacerbating the problem.

One such entrenched building practice required under the HUD code is the application of a vapor retarder on the interior side of exterior walls. Most building codes require the vapor retarder to be installed on the warm-in-winter side of the insulation. Exceptions are identified in the final draft of the International Residential Code 2000, by counties in hot, humid regions. While building scientists agree that in predominately hot, humid climates the vapor retarder belongs outside the insulation, this may be only one contributing factor when moisture problems occur and, depending on the circumstance, may not be the major factor. Further, once cause and effect are better established, and the relationship between moisture balance and building design and installation practices firmly established, better building methods can be readily identified.

The movement of moisture in homes is a dynamic, complex phenomenon. When moisture condenses on surfaces or in materials and building components, several unrelated factors may be the cause making it difficult to pinpoint strategies for avoiding moisture problems. The purpose of this effort is to pinpoint the major contributing factors to moisture-related damage in manufactured homes sited in hot humid climates; identify and/or develop construction, installation and operational alternatives that effectively control or reduce the flow of moisture; and disseminate findings to industry and consumers.

There are several tools that can be used to gain a better understanding of the sources of moisture problems and assess effective abatement strategies and they all have a role to play in this effort. They are: field analysis and surveys, laboratory testing and simulation analysis.

Field investigations of homes that have moisture-related damage and those that are similar but problem free (control homes) offer a real world laboratory for understanding the major problem sources and the kind of havoc they can wreak on building materials and components. Field study and survey are the starting point for this effort as they afford the opportunity to document the entire building dynamic and draw conclusions about how moisture problems originate and propagate. However, field study is limited in its ability to answer the “what if” questions, such as what if the thermostat was lowered, how would the tendency for moisture problems to develop be impacted. These kinds of questions are useful in both fully understanding moisture dynamics and in evaluating the impact of changes in building practice. Simulation and laboratory testing are ideal methods for dissecting the problems and examining the efficacy of alternative building methods. All three – field study, simulation and laboratory testing – will be used in this effort to gain a clear understanding of the major causes of moisture

problems in hot, humid climates and in developing and assessing practices that eliminate such problems.

Some of the factors that can contribute to moisture problems

Although the most significant causes of moisture problems experienced in the hot, humid climates are well known, the interplay of these factors and their relative importance in any one manufactured home is not well understood. As a result, one home may have moisture damage while an identical design in the same location is problem free. The major factors that can contribute to moisture problems include the following:

Placement of the vapor retarder on the inside of exterior walls. This increases the risk that moisture from outside air will accumulate within wall cavities of air-conditioned homes.

Ventilation of attic cavities. This allows moisture-laden air easy access to penetrations in the ceiling where it can enter the home and cause damage and condense on the attic side in the insulation or on the ceiling board.

Damage to the bottom board that often occurs during set up allowing moisture-laden air access to the floor cavity where it can come in contact with cold surfaces such as uninsulated metal ducts, resulting in condensation, pooling and material degradation. Duct leakage, that may have its origins in how the home was manufactured or set up, often exacerbates moisture problems by inducing moisture-laden outside air to be drawn into the home and building cavities.

Oversizing of air conditioning equipment often results in higher indoor humidity and lower thermostat set points, increasing the condensation potential and risk of moisture damage.

In humid climates, excess whole house ventilation and infiltration can introduce significant levels of unwanted moisture into the living space.

This study will establish the relative contribution to moisture accumulation made by each of these factors and will describe preventative actions that can be taken by the manufacturer, installer and homeowner.

Project tasks

Conduct a literature survey of residential moisture controls for hot, humid climates. An annotated bibliography of recent investigations, reports and studies covering residential moisture control in hot and humid climates will be generated. The results will be summarized in a concise document.

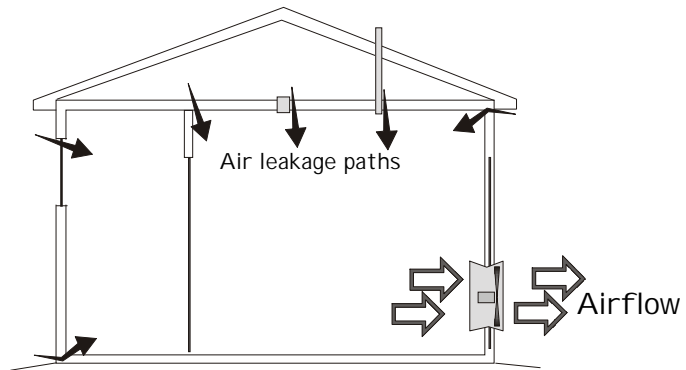
Characterize existing moisture problems in the hot and humid climates. Up to fifty manufactured homes located in the hot and humid climates including coastal areas of Texas, Louisiana, Mississippi, Alabama and Florida that have experienced moisture problems during the recent cooling seasons will be identified. Information required to completely characterize the construction, siting, operation, equipment performance, air retarder integrity and local climate that may have contributed to the moisture problems will be gathered for each home using identical protocols. Surveyors will suggest the likely genesis of the moisture problems. Data will be collected during field visits through a variety of methods including interviews, audit measurements, ventilation rate measurements, blower door and duct pressurization measurement. Selected homes, such as those with more severe problems, will receive a more thorough characterization

including infrared scanning, boroscope explorations and possibly short-term monitoring. Samples of construction materials and molds or other damage may be collected for analysis.

Investigate control homes showing no evidence of moisture problems. Up to fifty manufactured homes located in hot and humid climates that have shown no signs of moisture problems will be identified and surveyed. These will be matched with the homes in Task 1 to serve as a control group and will undergo identical characterization analysis. Although these homes will be used as a control group, possible evidence of early signs of moisture problems will also be recorded.

Establish relationships between building characteristics and moisture problems.

Researchers and practitioners will review the data and characterize the conditions that are likely to encourage moisture problems. These conditions will form a matrix of factors that individually or in combination can be shown to cause moisture imbalances and create the potential for problems.



Field investigations

Building airtightness – House airtightness, which can be thought of as the cumulative size of the holes in the building envelope, cannot be directly measured with a ruler or tape measure because the holes are widely distributed in

many cracks and penetrations. Leaks in the building shell can, however, be measured indirectly by measurement of the air flow rate through those leaks when the house is depressurized to a specified pressure. Airflow is measured in cubic feet per minute (cfm). Pressure is measured in Pascals. Airtightness is then expressed in terms of CFM50. The equipment used to make this airtightness test is the blower door. The blower door test is done by changing the building's static pressure relationship with the outdoors and noting the amount of airflow required for that change. As a result, the air leakage characteristics of a building

The blower door depressurization test is a procedure in which a powerful fan is attached in an external doorway and draws air from the house creating a negative pressure. Outside air is drawn in through all the holes, cracks and penetrations of the building envelope. The amount of air passing through the fan is measured and an overall building airtightness can be determined.

AIRFLOW AT 50 PASCALS - Some terms defined

CFM50: This is the airflow (in Cubic Feet per Minute) needed to create a change in building pressure of 50 Pascals. CFM50 is the most commonly used measure of building airtightness.

ACH50: The Air Changes per Hour at 50 Pascals is another commonly used measure of building airtightness. ACH at 50 Pa is the number of complete air changes that will occur in one hour with a 50 Pascal pressure being applied uniformly across the building envelope. ACH at 50 Pa is a useful method of adjusting (or normalizing) the leakage rate by the size (volume) of the building.

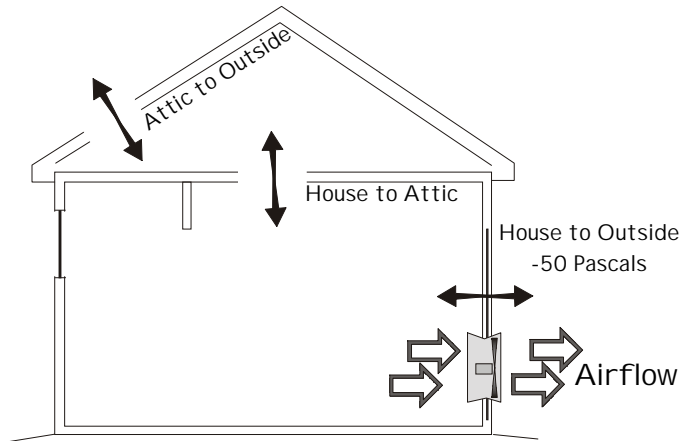
$$ACH50 = (CFM50 \times 60) / \text{building volume}$$

CFM50/square foot of floor area: This is the CFM50 reading for the building divided by the floor area of the building. CFM50/square foot adjusts (or normalizes) the leakage rate by the size (floor area) of the building.

$$CFM50/\text{square foot} = CFM50 / \text{floor area}$$

envelope can be evaluated. A testing protocol standard has been developed by the American Society for Testing and Materials (ASTM). It has the designation of E 779: Standard Test Method for Determining Air Leakage Rate by Fan Pressurization.

Often, the detailed output is not required that the ASTM standard provides. Many situations do not require leakage ratios, correlation coefficients, or effective leakage area. We merely want to know how much a building leaks at a specified reference pressure. The industry standard has become 50 Pa. A single-point test consists of simply reaching 50 Pa and reading the flow required to achieve that pressure difference. Single-point testing has gained wide use recently, especially with crews who do some diagnostic tasks and retrofit work. After the door is set up, it takes only a few seconds to do a single-point test.

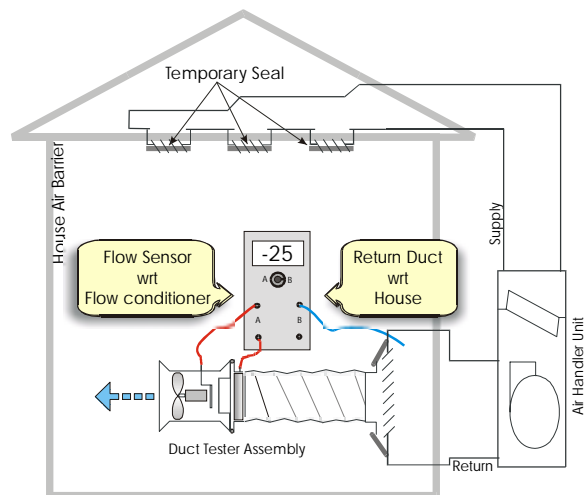


The relative size of the leakage rates of the house to attic and attic-to-outside can be determined with simple pressure measurements when the house is depressurized to 50 pascals. This method can be used to determine relative leakage rates of any zone in question.

Relative Size of Leakage		Measured Pressures	
House-Attic	Attic-Outside	House-Attic	Attic-Outside
2	1	12	38
1	1	25	25
1/2	1	37	13

Pressure mapping zones with blower door – *To determine some of the pathways and barriers to airflow that exist in the building, the building was depressurized with the blower door to a pressure difference of 50 pascals. The pressure difference is then measured across the ceiling, wall, and floor cavities to determine whether a pressure difference existed or not. When a pressure close to 50 pascals is measured, this indicates that the cavity under test is nearly outside.*

Duct System Testing – The duct system was tested for airtightness using a duct test apparatus such as the Minneapolis Duct Blaster . This device operates similar to the blower door apparatus and measures the leakage or airtightness of the duct system. All of the supply registers and return grilles are closed off with a temporary seal and the duct tester is attached to the return grill. The system is



Typical depressurization test. Total CFM25 leakage of the duct system can be determined. A tight system would have leakage rates less than 5% of the rated air handler flow.

then depressurized to 25 pascals (0.1"wc) and the airflow required to achieve that pressure is measured. A perfectly airtight duct system would have zero leakage or the CFM25_{total} would be 0. An additional test that determines the amount of leakage outside the conditioned space is also completed. Known as a CFM25_{out} test, it requires that both the duct tester and blower door fans to operate simultaneously. Both the house and the duct system are maintained at -25 pascals with reference to (wrt) outdoors, i.e. the duct system wrt house = 0 pascal

Pressure Mapping with the Air Handler Fan – Normal operational pressures that exist within the building define the potential and direction of airflow (the opening would need to be characterized to know the quantity of flow). A series of pressure differential measurements are taken when the air handler fan operates at high (or cooling mode) speed. Duct system leakage effect can be seen with a differential pressure measurement across the front door of the building. Supply side leakage tends to depressurize a building and return side leakage tends to pressurize a building. The bedroom doors are opened and closed to determine the effectiveness of return air pathways. Ideally, all of the pressure differential measurements should be very close to zero.

Data Collection – The data to be collected is outlined on the data collection form. This information is gathered and sent to MHRA for analysis. In addition to the diagnostic test results from each house, the following characteristics are collected:

Site Characterization

Observed Moisture

Wall

Ceiling

Floor

Visual & Interview Findings

Noted problems

Operation of equipment

HVAC Equipment

Type and condition of equipment

Type and use of ventilation equipment

Type of air distribution system

Other Notes:

Describe any previous repairs:

Describe wall layers if possible and if outer sheathing is "ventilated"

Sample Data Collection Form

Site Characterization

Investigation Date: (Mon/Day/Year) _____ Date Built _____ HUD/Serial No _____

Location: City or Zip _____ TX LA, AL, MS, GA, SC, FL, NC

House Size: (square feet) Single Double Triple-section

Thermal Zone: 1 2 3 Wind Zone: 1 2 3

Microclimate: Dry Floods Damp NearWater |Sun: Full Shaded |Wind: Exposed Protected

Long side of home faces: N NE E SE S SW W NW

Observed Moisture Problems (Present condition, identify for each distinct problem)

Floor Ceiling Walls |LOCATION: A Side B Side Marriage End Light Register Other

Wall-Problem Type: Vinyl Papered Lauan Tape & Texture Combination

Location: Perimeter End Perimeter Long Interior Marriage Closet Sunny Shady

Ceiling-Problem Type: Cathedral Flat Transition Other

Location: Peak Ex Walls Interior Walls Lights Registers Closet Other

Floor-Problem TYPE: Vinyl Carpet Other

Location: Utility Kitchen Bath Bed Living Closet Other

Structural failure? 1-10 ft2 10-100 ft2 100+

Bowing & Buckling? 1-10 ft2 10-100 ft2 100

Mold or Staining Present? 1-10 sq ft 10-100 sq ft 100+

Other Problem? No Yes

Describe: _____

Visual & Interview Findings

As found interior temperature: _____ F Reported Summer setpoint: _____ F AHU Fan: On Auto

Number of People in home: _____ Pets _____ Other H2O Sources?

Tears in belly board? No Yes Estimate Total _____ Square Feet

Ground cover present? No Yes Estimate Total _____ % Covered

Dryer duct dumping into crawl? No Yes Excessive Drier Use? No Yes

Suspect unsealed marriage line? No Yes

Evidence: _____

Doors that are typically closed: MBed Other Bed AHU Zone Most Doors Day Night

HVAC Equipment

A/C Capacity: Compressor Make _____ Model _____

Indoor Coil Type 2-row 3-row 4-row Line-set sealed? No Yes

Filter: Very Dirty Dirty Clean Coils: Very Dirty Dirty Clean

Condensate drains to outside? No Yes

AHU fan setting: Heat: Lo MedLo MedHi Hi Cool: Lo MedLo MedHi Hi

Vent strategy: Blend Air Dampened intake at A/H Up/On/Down-stream of coil Hall Fan Other

Vent function: Working as Designed Failed Intentionally Disabled Always Off Always On

Ducts: Metal Fiber Board Flex Floor Attic Provide simple duct layout sketch

Diagnostic Test Results

House Duct Leak, total CFM25total _____ Duct Leak, total CFM25out _____
 CFM50 _____

Hse-Belly A/H-side _____ B-side _____ Hse-Attc, A/H-side _____ B-side _____

Hse-Damaged Wall _____ Hse-Good Wall _____ Hse-Marriage wall _____

Pressure mapping (Pa)

Hse-Out all off _____ Hse-Out ahu on _____ Hse-Out ahu on MS door _____ Hse-Out ahu on all door _____

Mbed-hse _____ Bed2-Hse _____ Bed3-Hse _____ Utlity-Hse _____ Hse-Out, Max depressurization _____

Other Notes:

Describe any previous repairs:

Describe wall layers if possible and if outer sheathing is "ventilated"

Partial Collected Data Set from North Carolina by Blue Sky Foundation

#	Buil t	SqFt	CFM50	CFM25total	CFM25out	Hse-Out (pascals)			Mbed-Hse	Mold ?	
						Interior Open	MS Door Closed	Interior Closed			
52	2000	1500	1580	165	133	-0.3	-0.5	-2.7	-3.3	8.2	n
53	1996	2340	1729	124	89	-0.2	-0.3	-1.4	-1.8	0.4	n
54	1999	1512	1764	150	54	-0.7	-1.4	-3.0	-4.3	4.1	y
55	1997	1512	1816	196	120	0.2	-0.4	-1.9	-2.5	2.8	n
56	1997	1824	2267	124	0	0	-0.5	-1.4	-1.2	4.0	y
57	2000	1809	2294	160	84	0.6	-1.4	-2.5	-2.3	4.6	n
60	1999	1846	2990	102	0	0.4	0.2	-1.4	-2.0	3.0	n
61	2000	1224	2062	320	124	1.2	-2.2	-3.5	-5.3	5.1	n
62	1997	1030	1347	89	71	-1.5	-0.4	-2.4	-3.0	5.1	n
63	1998	1524	2163	122	92	AHU OFF -0.4	AHU ON -1.0	-2.4	-3.7	6.0	n
67	1997	1539	2267	122	89	AHU OFF 0	AHU ON -0.4	-1.2	-1.8	4.0	n

72	199 9	1416	1447	179	87	0.1	-1.9	-2.7	-3.0	2.7	y
74	199 9	1584	1747	130	89	-0.2	-0.5	-1.0	-3.3	7.0	n
73	200 0	1824	2398	170	89	0.7	0.1	-1.5	-4.3	1.8	n
79	200 0	948	2062	116	87	0	-0.2	-0.4	-1.0	4.4	n
85	199 9	1344	1520	155	88	0.2	-1.0	-2.0	-3.2	3.0	N

Bold numbers – reworked from original collected data

Final Results

The final results will be published by MHRA once data has been received by all of the collection teams and analyzed. The analysis will try and establish relationships between building characteristics and moisture problems. Researchers and practitioners will review the data and characterize the conditions that are likely to encourage moisture problems. These conditions will form a matrix of factors that individually or in combination can be shown to cause moisture imbalances and create the potential for problems.

To test cause and affect hypothesis, data from the field study may be used with moisture flow simulation models. These models predict the sensitivity of moisture balance to changes in a variety of factors and predict how the altering construction methods, design decisions and home operation can minimize the risk of future problems. Alternative component designs will be ranked by their ability to control moisture, ease of construction, versatility, compliance to the HUD code, cost and other factors. It is expected that this work will be completed and published in 2002.

Database tab for collecting information about air leaks and moisture problems in home. Information used in evaluating homes air tightness and moisture issues.

This screenshot shows a data entry form for home air leaks and moisture issues. The form is organized into several sections:

- Investigation Date:** Includes fields for Year Built, City, State (pre-filled with 'NC'), and HUD No.
- Thermal and Wind Data:** Fields for Thermal Zone, Wind Zone, Microclimate, Sun, Wind, MFH Square Ft., Type of MFH, and Long Side MFH Faces.
- Observed Moisture Problems and Location:** A section with checkboxes for Floor, Ceiling, Walls, and various locations (A side, B side, Mantel, End, Light, Register, Other).
- Problem Details:** Two columns of text input fields for Wall Problem Type, Wall Location, Ceiling Problem Type, Ceiling Location, Floor problem Type, Floor Location, Structural Failure, Bowing and Buckling, and Mold and Staining Present.
- Other Problems:** A checkbox for 'Other problems' and a text field to 'Describe Other Problem'.

Database tab for second part for collecting information on air leaks and moisture problems with home. Like first air leak/moisture tab this information was used in the 16 homes examined for energy/moisture issues.

Database tab for 1st survey questionnaire. Consist of general home owner information.

This screenshot shows a data entry form for general home owner information. The form includes the following fields:

- County:** A text input field.
- Living:** A text input field.
- First Name / Last Name:** Two text input fields for the owner's name.
- Physical Address:** A set of five text input fields for the physical address, labeled F_Addr.1 through F_Addr.5.
- Mailing Address:** A set of four text input fields for the mailing address, labeled M_Addr.1 through M_Addr.4.
- Home Phone:** A text input field.
- Cell Phone:** A text input field.
- City Phone:** A text input field.
- Email Address:** A text input field.

Database tab for natural hazard experiences and preparations taken for storms. Gives a sense of who experienced high wind events and what, if any damage was done.

This screenshot shows a web-based form for collecting data on natural hazard experiences. The form is organized into several sections with checkboxes and text input fields:

- Flood Hazard:** A checkbox labeled "Flood Hazard" and a text input field labeled "Flood Hazard Discrip".
- Experiences Hurricane:** A checkbox labeled "Experiences Hurricane" and a text input field labeled "Approx wind speed".
- Action taken B4 Hurricane:** A checkbox labeled "Action taken B4 Hurricane" and a text input field labeled "Where where during Hurricane".
- Sustain Hurricane damage:** A checkbox labeled "Sustain Hurricane damage" and a text input field labeled "Damage descriptio".
- Take high wind precaution:** A checkbox labeled "Take high wind precaution" and a text input field labeled "What precautions are taken in the event of high win".
- Take structural preparations for it:** A checkbox labeled "Take structural preparations for it" and a text input field labeled "Describe how structure is prepared for a major s".
- Would anything different be done for next stor:** A text input field.

Database tab for collecting home energy source and what, if any, water mold damage has occurred.

This screenshot shows a web-based form for collecting data on home energy sources and water/mold damage. The form includes the following sections:

- Types of Heating and Cooling systems on MFH:** A heading followed by a row of checkboxes for "AC", "Heat Pum", "Electri", "Gas", and "Portable Window A".
- Own a free-standing or un-vented appliance:** A checkbox followed by the text "(like kerosene heater, e".
- Any water or mold damage:** A text input field.
- If YES, describe water or mold damag:** A text input field.

Database tab for collecting demographic information on home-owner and family. Gives an idea of who participated

This screenshot shows a form for collecting demographic information. The fields are as follows:

- Number of children under 18 in Pa: [Text input]
- Boys Ages: [Text input]
- Girls Ages: [Text input]
- Owner Age: [Text input]
- Owner Gender: [Text input]
- Highest grade complete: [Text input]
- Estimated value of home: [Text input]

Database tab for collecting on site visual information and information about homeowner experiences with home.

This screenshot shows a form for collecting on-site visual information and homeowner experiences. The fields and options are as follows:

- Foundation: [Text input]
- Access under MF: If access is "Yes", then give Underpinning Drop: [Text input]
- Have Setup Manual:
- Was MFH Altered: What was altered: [Text input]
- Have dogs
- Willing to do stuf
- Is water in crawl space
Describe water in crawl space: [Text input]
- Ever experience problems with MF
Experienced problem esp: [Text input]
- Description of problem: [Text input]
- Recommendations to Manufactur: [Text input]

Database tab for collecting homeowners utility, insurance, and energy source information. Gives us permission to contact named companies for future work.

This screenshot shows a web form with the following sections:

- Permission to contact Ins Company:
 - Ins company: [text input]
 - Ins Agent: [text input]
 - Ins Phn: [text input]
 - Ins Acct #: [text input]
- Permission to contact Gas or Propane:
 - Propane/ Gas Co: [text input]
 - Propane/Gas Phn: [text input]
 - Propane/Gas Acct #: [text input]
- Permission to contact Elect:
 - Electric Co Name: [text input]
 - Electric Co Phn: [text input]
 - Electric Co Acct #: [text input]
- Utility Authorization Form Req

Database tab for collecting home size, GPS location, serial number, etc for research use. Same page will link pictures or each entry in database.

This screenshot shows a web form with the following sections:

- Dist to open water: [text input]
- Perimeter of MF: [text input]
- Latitude and Longitude: [text input]
- Bearing of front of house: [text input]
- Height of home: [text input]
- Size of roof: [text input]
- Attitude: [text input]
- Dist from street to home: [text input]
- Corner of house measured fr: [text input]
- Home built on: [text input]
- Propane Tank? if yes, tank down?
- HUD Number: [text input]
- Serial Number of form: [text input]

Command: 1487

Database tab for collecting on site soil data for footer & pier size need.

Soil Classification: (see Classification table)

Soil Description: (e.g. "dark brown, sandy soil w/rocks")

Pocket Penetrometer		Torque Probe	
Reading 1	Reading 2	Reading 1	Reading 2
1	<input type="text"/>	1 ft	<input type="text"/>
2	<input type="text"/>	2 ft	<input type="text"/>
3	<input type="text"/>	30 in	<input type="text"/>
4	<input type="text"/>	3 ft	<input type="text"/>
5	<input type="text"/>	4 ft	<input type="text"/>
ave	<input type="text"/>	5 ft	<input type="text"/>

Comments:

Database tab for collecting information about on site foundation condition. Crucial for evaluating homes potential risk in tipping in high wind environment.

Exterior Condition:

Chairs and Floor J:

Pier Condition:

I-beam size:

I-beam spacing:

pier constructio:

pier foundation typ:

pier caps:

total num pier:

max pier space ft:

min pier space ft:

max pier height:

min pier height:

innovative pier mat:

foundation damage

wedges on each sid

wooden caps/wedges rotte

perimeter blockin

CMU holes facing u

Foundation comm:

Database tab for collecting information about anchoring and strapping type, condition, and size for homes. Crucial in evaluating homes risk to uplift and tipping in high wind environment.

This form is used for collecting data on anchoring and strapping. It includes the following fields:

- Total number anchor
- Strap Label
- Bolt label
- Stabilizer plate
- Sidewall Strap
- # of Sidewall Anchor
- Label/Model SW Anchors
- SW anch w/o SW straps
- SW Anchor Attachment
- SW Attachment to frame
- Angle SW Strap to Frame
- # straps in SW anch
- # Centerline anchors
- Label/Model CL anchors
- CL Anchor Attachment
- # straps in CL anchors
- Straps Vertic
- # Endwall Anchors
- Label/Model EW anchors
- EW Anchor Attachment
- EW Attachment to frame
- Angle EW strap to frame
- # straps in EW anchors
- with tight straps
- not flush w ground
- dist ground to base
- bent anchors
- angled improperly
- straps with end
- bolts not locked in
- anchor do remain in
- bolt life remain in
- strap splice type
- Mascot hole

Database tab for collecting information about air leaks and moisture problems in home. Information used in evaluating homes air tightness and moisture issues.

This form is used for collecting data on air leaks and moisture problems. It includes the following fields:

- Investigation Date
- Yr Built
- City
- State (NC)
- HUD No.
- Thermal Zone
- Wind Zone
- Microclimate
- Sun
- Wind
- MFH Square Ft.
- Type of MFH
- Long Side MFH Faces
- Observed Moisture Problems and Location
 - Floor
 - Ceiling
 - Walls
 - Location: A side, B side, Marraig, End, Light, Register, Other
- Wall Problem Type
- WP Location
- Ceiling Problem Typ
- CPT Location
- Floor problem Type
- FP Location
- Structural Failure
- Bowing and Buckling
- Mold and Staining Free
- Other problems
- Describe Other Problem

Database tab for second part for collecting information on air leaks and moisture problems with home. Like first air leak/moisture tab this information was used in the 16 homes examined for energy/moisture issues.

Cal/Moisture 2

Interior Temp	Reported Summer Setpoint	AHU Fan	Number people in Home
Number of pets in Home	Other H2O Sources	<input type="checkbox"/> Tears in Belly Board?	Estimated Total Tear
<input type="checkbox"/> Ground Cover Present?	Estimated Total Cover	<input type="checkbox"/> Dryer Duct Dumping into Crawl?	<input type="checkbox"/> Excessive Dryer Use?
<input type="checkbox"/> Suspect unsealed marriage line?	Doors that are typically Closed		A/C Capacity:
Evidence	<input type="checkbox"/> NBed	<input type="checkbox"/> Moist Doors	Make
	<input type="checkbox"/> Other Bed	<input type="checkbox"/> Day	Model
	<input type="checkbox"/> AHU Zone	<input type="checkbox"/> Night	Indoor Coil Type
			<input type="checkbox"/> Line-set Sealed?
Filter:	Coils:	AHU Fan Setting	
		Heat	Cool
		<input type="checkbox"/> Condensate Drains to Outside	
		Vent Strategy	
		Vent Function	
Ducts:	House CPM21:	Duct Leak, total CPM2total:	Duct Leak, Total CPM25out:
Hse-Attic A/H-Side:	Hse-Attic B-Side:	Hse-Damaged Wall:	Hse-Good Wall:
Hse-Marriage Wall:	Hse-Out all off:	Hse-Out ahj on:	Hse-Out ahj on MS door:
Hse-Out ahj on all door:	Mbed-hse:	Bed2-Hse:	Bed3-Hse:
Bed4-Hse:	Other Notes:		
Libty-Hse:	Hse-Out, Max Depressurization:		

Interior Temp _____ Reported Summer Setpoint _____ AHU Fan _____ Number people in Home _____

Number of pets in Home _____ Other H2O Sources _____ Tears in Belly Board? _____ Estimated Total Tear _____

Ground Cover Present? _____ Estimated Total Cover _____ Dryer Duct Dumping into Crawl? _____ Excessive Dryer Use? _____